

THE EFFECT OF HERD SIZE ON THE SERO-PREVALENCE OF *SALMONELLA* *ENTERICA* IN DANISH SWINE HERDS

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This paper evaluates the effect of herd size on the sero-prevalence of antibodies against *Salmonella enterica* based on data from the nation-wide salmonella control program (Mousing et al. 1997) taking into account the effects of date of slaughter (season) and geographical county of the herd. Since, there were multiple measurements from each herd, we needed to account for the dependence between samples from the same herd. This led us to construct a random-effects model which allowed interpretation of the size of the fixed effects in relation to the size of the variance of the random effects, that is to quantify the effect of the known variables (included as fixed effects) in relation to the variation in those not known (modelled as random effects). This means that the focus of the statistical modelling will be moved from significance testing of effects to estimation of effects and interpretation of the importance of these relative to each other and relative to the subject matter.

MATERIAL AND METHODS

The data were extracted from the official Zoonosis Register (ZOOR). A total of 510,915 meat juice samples from 14,593 herds located in 13 counties (out of 16 in Denmark) were included in this study. The study period was from October 1994 to December 1995. For more detailed information on the materials, please refer to Carstensen and Christensen, 1997.

The data on each sample comprised information on county, the annual number of pigs produced (farm level variables), date of sampling and OD-value (Optical Density)(sample level variables). The OD-value used throughout is a transformed OD%: all OD% less than or equal to 11 were recorded as 1 and all other as the OD% minus 10.

The association between herd size and sero-prevalence of *Salmonella* was assessed in a random effects model with herd size, date of slaughter, and county as fixed effects (Carstensen and Christensen, 1997) and with random effects of herd, herd size by county interaction and herd size by date of slaughter interaction. The model is a generalized linear mixed model for data dichotomized at OD-value 30 and transformed to the $-\ln(-\ln)$ -scale.

RESULTS

The overall *Salmonella enterica* sero-prevalence in the material was 5.4% using a cut-off OD-value 30. The results from the stratified variance component model were summarized in

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tables 1 and 2 for cut-off OD-value 30. For simplification the tables show the range of the fixed effects. For herd size the estimated effects increased from 0.00 to 0.08 when the herd size increased from 200 to 2000 pigs per year (Tab. 1).

The herd-size effect was the smallest of the fixed effects although, almost of the same order of magnitude as the other two fixed effects. The range of the fixed effect was around 0.2 on the $-\ln(-\ln)$ -scale (Tab. 1). The size of the standard error of the random effects was of the same magnitude for the county \times herd size interaction (0.26), and a little smaller for the date \times herd size interaction (0.12), whereas the within herd and between herd variations were somewhat larger 0.70 and 0.58, respectively.

Although the fixed effects were clearly significant, they were of little value in prediction of salmonella occurrence. Any prediction will end up almost totally uninformative owing to the large random variations. This is clear from table 1, where, in particular, the contributions from the between- and within-herd effects render predictions uninformative.

DISCUSSION

All investigated fixed effects were significant, but that is due to the large sample size (510,915 meat-juice samples and 14,593 herds). The relative risk of exceeding OD-value 30 associated with a ten-fold increase in herd size from 200 to 2000 pigs slaughtered per year was merely 1.66 (Tab. 2). It was of the same magnitude as the relative risk of a positive test between the date with the lowest prevalence (July 1995) and with the highest prevalence (November 1995). In contrast, the relative risk between the counties with the greatest difference in prevalence was 5.13.

Table 1. The estimated effects from the stratified random effects model for 516,915 meat juice samples from 14,593 Danish swine herds. All estimates are on the $-\ln(-\ln p)$ -scale

Parameter	Cut-off OD-value 30	
Fixed effects (the largest difference in estimated effects)		
		Range
Herd size (200 - 2000 pigs/year.)	-0.01 to 0.12	0.13
County	-0.22 to 0.16	0.38
Date	-0.05 to 0.12	0.17
Random effects (statndard errors)		
		Media n
Within herds	0.58-0.90	0.70
Between herds	0.35-0.80	0.58
County×herd size	0.26	
Date×herd size	0.12	

Table 2. Estimated effects on the prevalence scale (in %) from the stratified random effects model for 516,915 meat juice samples from 14,593 Danish swine herds. The estimated prevalences are for the indicated ranges of parameters from table 1, but transformed to the prevalence scale. The estimates are for herds with all other effects 0

Parameter	Cut-off OD-value 30	
	Prevalence	RR
Fixed effects (the largest difference in estimated effects)		
Baseline prevalence	1.55	
Herd size (200 - 2000 pigs/year.)	1.49 to 2.48	1.66
County	0.56 to 2.87	5.13
Date	1.25 to 2.48	1.98
Random effects ($\pm 1.64 \times$ median)		
Within herds	0.00-26.78	-
Between herds	0.00-20.09	-
County \times herd size	0.19-6.32	33.3
Date \times herd size	0.62-3.37	5.3

Since the power of the study was high, it is important to evaluate the relative magnitude of the estimates of the fixed effects and the magnitude of the standard error of the random effects. For example, the standard error of the herd effect (0.58) was approximately four times the range of the effect of herd size (-0.01 to 0.12 range 0.13) on the $-\ln(-\ln)$ -scale (Tab. 1).

The interpretation was that there were other factors than herd size, county, and date that may be biologically more important because they potentially explain more of the variation in salmonella occurrence.

The standard error of the variation between herds was slightly smaller than the standard error of the variation within herds (proportions of total variance were respectively $0.58^2/(0.70^2+0.58^2+0.26^2+0.12^2) = 37\%$ and $0.70^2/(0.70^2+0.58^2+0.26^2+0.1^2) = 54\%$). Since both the variances within and between herds were relatively high, we concluded that other (unknown) factors may be acting at the herd level as well as at the pig level.

The factors acting at the pig level may be: type of pen separation, pig density in the pens, presence of other diseases, and distance to a pig excreting salmonella. Factors acting at the herd level may be wet feed/dry feed, on-farm produced feed, slurry/manure management, cleaning/disinfection procedures, and pig density in the geographical area. Some factors may act at different levels; for example all-in/all-out could be practised at the herd, house, or pen level.

The potential complexity of the factors influencing the occurrence of salmonella-antibodies indicates that a series of investigations is necessary to fully describe them. Some studies will have to focus on herd level factors while other should focus on the pig level.

There was no indication that the study sample should not be representative of the Danish swine population with regard to herd size, county, and date of slaughter after June 1995. The study included $14,593/16,672=88\%$ of the farms with pigs above 50 kg live weight and 2.9% of the pigs produced in Denmark during 1995. The sampling intensity increased during 1995, and therefore more samples were taken in the second part of 1995 compared to the first part, but the comparison July to November should be valid.

CONCLUSIONS

Herd size had a statistically significant effect on the sero-prevalence of antibodies against *Salmonella enterica* — but it was biologically of little importance, because the within-herd and the between-herd variances were relatively large in comparison.

The relative magnitude of the variance components indicated that factors associated with both the herd level and the pig level could be important in the prediction of sero-prevalence of *Salmonella enterica*.

REFERENCES

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